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Analysis of the water gave the following results per liter:

SiO ₂	.0280 grams.	Na ₂ O	.0244 grams.
SO ₃	.0550 "	H ₂ O combined.....	.0746 "
Cl.....	.0176 "	CO ₂ combined	.3644 "
FeO.....	.0454 "	Total.....	.8320 "
CaO.....	.1625 "	Less Cl as O.....	.0040 "
MgO.....	.0356 "	Total solids.....	.8280 "
K ₂ O.....	.0245 "		

The probable combination in grains, per U. S. gallon, is as follows:

SiO ₂	1.6324	MgH ₂ (CO ₃) ₂	5.1712
NaCl	1.6907	CaH ₂ (CO ₃) ₂	27.4126
Na ₂ SO ₄	1.2010	FeH ₂ (CO ₃) ₂	6.5471
K ₂ SO ₄	2.6410	Total solids	48.2724
MgSO ₄	1.9764		

WATER-SUPPLY FROM A SANITARY STANDPOINT.

BY F. O. MARVIN, C. E., UNIVERSITY OF KANSAS, LAWRENCE.

A lecture delivered before a special meeting of the Academy, at Topeka, January 25, 1901.

As a close student of the animated forces of nature becomes more and more familiar with the various individual species that make up the complicated fauna and flora, and with the way in which she carries on the life processes of the different organizations, the more is he forced to a recognition of the fact that there is a constant struggle for individual existence. Life preys upon life. The higher types attack and kill the lower, appropriating them for food or getting them out of the way if inimical to their development. In turn, throughout the whole range of living organisms, the lower resists this attack and appropriation, and through the multiplicity of numbers or a counter-attack in the domain of parasitism, seeks to maintain and perpetuate its own. Just in proportion as any type acquires an ability to ward off attack from its enemies on the one hand, and on the other to utilize the vital energies of those of the lower types that can assist in any way in its own permanence, does it have chance of a natural and continuous evolution of its own traits and characteristics.

Man himself is not exempt from this struggle, but he has the advantage of a higher intelligence, which, unfortunately, he does not always exercise to his benefit. He often so orders and conducts the affairs of his daily life as to create conditions favorable to the rapid and continued development of his natural enemies, while neglecting those that favor his natural friends.

Air, water, food and the soil are the natural possessions of man, and each individual has an inalienable right to their use. If he is to derive the maximum of benefit from the exercise of this right, these elements must contain nothing that is harmful to him; that is to say, that the air must be clean, the water safe, the food good, and the soil unpolluted. Absolute purity in these elements has no practical existence, and it is useless to insist on such; but it is well within the individual right to demand that these shall be free from harmful contaminations, so that they may be used with safety. This individual right also carries with it an individual responsibility, viz., the avoidance of any personal act, whether wilful or otherwise, that may render these elements unsafe to others.

Primitive man could easily move his local habitation to one of better environment when he found the results of his own living were detrimental to either him-

self or his neighbor. Modern man, on the contrary, is a fixture in one location, and this, together with his gregarious habits, tends to a concentration of the waste products of his own activity, a system of life that we boastfully call civilization. This brings evil through rendering these common heritages unsafe for use. The very best and keenest intelligence of the race has been and is being brought to bear on the problems that have arisen under these conditions. Much has been learned of the means to be employed to avoid or lessen its effects, but there are still many things that are seen but imperfectly—many problems still unsolved. It is the province of this paper to briefly summarize the condition of our knowledge with reference to one of these elements, viz., water. In view of the fact that nearly five-sixths of the human body is composed of water, and that five or six pints are required daily for its sustenance, it would seem that every intelligent person possessing a lively instinct of self-preservation should desire to be possessed of all possible knowledge relating to its quality and the matters carried by it.

The sources from which supplies are obtained are four: From cisterns that catch and store the rainfall from roofs; shallow wells for the supply of isolated dwellings, or, when built larger or coupled together, for the supply of towns; deep wells, furnishing artesian water; rivers, or lakes and ponds, either natural or artificial. The common source is the rainfall, and it may clear the discussion if we trace this through its various stages, before it appears in a private or public supply. The water vapor that has arisen from the surface of land or ocean is condensed and falls as rain, washing the air of its mineral and organic dust, and absorbing also soluble gases, if any are present—ammonia, carbon dioxide, sulphur oxides, etc. Even the rainfall, then, is not pure water, and when gathered from city roofs it is further made more impure by the roof washings; so that cisterns often contain a considerable quantity of mineral and organic matter, either dissolved in the water or found at the bottom in a putrescent mass. In the smaller towns it is not likely that the amount and character of such impurity will be detrimental to the health of those that use the water, if cisterns are kept reasonably clean; but in larger places, where dust and smoke are much more abundant, such water may be at least objectionable to the senses of sight and smell, if not absolutely harmful.

When the rain falls on the ground it gives up to the vegetation its ammonia, and in return takes up from the soluble rocks certain of their salts and washes from the soil its earthy or organic dust, thus becoming richer in carbon dioxide and albuminoid ammonia, and with increased solvent power. Flowing from the highlands to the regions of forest and plain, various organic substances are extracted which add to the impurity of the water, and often give it a decided color. An undulating country, overlaid by sandstone formations and covered by a succession of forest and meadow and peaty bog, furnishes a brown or amber water, the color being derived chiefly from decomposed and caramelized carbonaceous matter. The water flowing from a limestone region, where the rocks are of a more soluble character and have given up some of their elements, is more apt to be colorless, though harder than the brown waters, and often containing as much, or more, organic matter. The rills and rivulets run together to form the larger streams, adding constantly to their burden of suspended or dissolved matter, both mineral and organic. The former kind of these impurities does not trouble the sanitarian when dealing with a surface-water, unless the matter is present in an excessive amount, as is the case with some of our larger western rivers. And here the difficulty is one connected with the appearance of the water or the disagreeableness of its use, rather than on account of any direct bearing that the

presence of the mineral constituents may have upon the health of the consumers. But with the organic matters of a water we have much to do, because these do have an influence upon health.

It is, then, essential that we should know in what ways this organic matter appears in a water, what changes it undergoes, what life activities accompany these, what becomes of it, how its history is recorded, and how all this is related to its safe use. It must be said in the outset that even such amounts of organic matter as would offend the sight or our sense of smell are not necessarily injurious to the human system. It is probable that they do affect us by weakening our power of resistance when attacked by disease, but we do not know as yet in just what way. However, observation and experience have taught us that its presence is frequently accompanied by living organisms that seek to fasten upon us, to set up disease or cause death. Hence, to the analyst or engineer who is called upon to judge of the character of a water as to its fitness for human use, the mere presence of these organic matters will not lead to a condemnation, but will be regarded as a danger signal which it is wise to heed, even to the total rejection of the water when the organic matter indicates conditions favorable to the presence of disease germs.

In making an analysis of water the chemist singles out the nitrogen as the significant substance, because this forms so large a part of the objectionable matter. In the first stages of the change in vegetable or animal tissue, this appears in the form of certain compounds of ammonia which are derived from the organic nitrogen of dead matter through the agency of several forms of low plant life—the molds, fungi, and certain species of bacteria, which attack it and break it up. This is the process of putrefaction. It may take place in the absence of air, and may be accompanied with the evolution of foul odors. When the insoluble organic nitrogen has been thus changed into the soluble forms of albuminoid and free ammonia, these in turn are attacked and broken up into new compounds by other species of bacteria, provided that there is present a sufficient small amount of oxygen, as this is a necessary element of their life. In the result, the nitrogen, as nitrous acid, unites with various bases to form nitrites. Then another set of bacteria requiring more oxygen work these over into nitrates, a final stage, when the nitrogen has lost its organic character and become completely oxidized and mineralized.

The principal factors in bringing about all these changes are the bacteria, a class of very minute microscopic plants, very little known twenty-five years ago, but which have been recently studied the world over. We have learned many things about them, and have put some of them at work to do our bidding, illustrations of which will be spoken of later.

But we have not done with the changes that take place in our nitrogen. After it has reached the condition of nitrates it is in proper form to become the food of plants higher in the scale than those that had used it before. These are small, almost microscopic, chlorophyll-bearing plants, and consequently having greenish colors, that float about freely in the water or become attached to larger growths. They appropriate the nitrates and restore them again to organic forms within their own structure. Then these algae become the food of the lower animal life, or, perhaps, die from excess of numbers or lack of sufficient food; when the dead matter is attacked anew by the bacteria. This completes the cycle of the nitrogen—organic nitrogen, the soluble ammonia compounds, the nitrites, the nitrates, and back again to organic state.

This cycle is not always complete. If the ammonia compounds are set free under conditions of little or no oxygen, the nitrifying organisms do not find all

that they need to do their work, notwithstanding that the food is plenty. If the change has been carried to the nitrate stage, the algæ cannot appropriate its results in the absence of light and oxygen. Sometimes there may occur an apparent retrograde movement. If, in the case of a water rich in nitrates, there be an addition of organic matter capable of decomposition, together with the organisms capable of doing the work, they may take the little oxygen that they need from the matter already oxydized, so that an analysis would show a less quantity of nitrates and an increase in the amounts of nitrites or ammonia.

A right understanding of the changes through which the nitrogen goes is essential to a correct interpretation of any water analysis. A strong tendency to stability in the form of the nitrogen is a favorable indication. A state of change is a condition of danger. Large amounts of ammonia or nitrites indicate an incomplete purification, and also a recent contamination. High nitrates indicate the oxidation of the organic matter, but also that there was a previous contamination at some time. If large numbers of bacteria are found, this points to an abundant food supply and to an active state of change.

The chief difficulty in drawing conclusions from the presence of nitrogen lies in its instability and the rapidity with which the changes occur. There is a substance, however, chlorine, that preserves its character through all the changes under which water is modified. Almost all waters have some amount of this substance present, and this is fairly constant for any given locality. When this normal amount is determined by examinations of waters known to be free from pollution, the finding of any excess over this normal in any water may be fairly assumed as indicating organic pollution; and inasmuch as chlorine always forms one of the constituents of sewage, such pollution can be traced to the discharge of a town's sewage into a stream, or the leakage of the contents of a cesspool into a private well.

The interpretation of a biological analysis of a water is a much more difficult matter than that of a chemist's investigation. The science of bacteriology is so new that we do not as yet know just what to look for on the one hand, or, on the other, just how to do it. But our knowledge is being added to faster than one can easily keep pace with it. So far, the only biological analysis that has come into general use, outside of laboratories devoted chiefly to some special scientific investigation, is a quantitative one, being simply an estimation of the number of the bacteria in the water, made from a count of those present in a small volume of it. As has already been said, if large numbers are found, there is indicated a strong activity and rapid change. But what we want to know is much more than this: just what species are at work, what are their life-histories, how they act and react on each other, which ones are detrimental to us and which ones are our helpers, and how we can put them to work.

We have learned how to isolate and study the habits of many of these microbes, but not all of them. We know, in a general way, how our friends, the saprophytic bacteria, or the scavengers that accomplish the work of putrefaction, do their work. The nitrifying organisms, also our friends, we are fairly well acquainted with. By a combination of chemical and biological methods, the expert can often trace a sewage contamination for long distances. Indeed, a microbe or microbes that surely indicate such source of impurity can be found long after the chemist fails to find any trace of such contamination, because of the degree of its dilution in the water. Many of the germs of water-borne diseases, such as typhoid, cholera, and malaria, are known, and have been studied. We also know, in a general way, that the conditions which are favorable to the growth and development of the minute organisms which are our friends are not favorable to

the life of those which are our enemies. But this relationship has not yet been worked out. Then, too, there are no practical tests that can be applied to a water by which the presence of these dangerous germs may with certainty be detected. Perhaps no such tests will ever be found, because of the comparative small number of the enemy that may find their way into the water, and the consequent small probability of catching some of them in taking any sample for examination. Probably we shall have to remain content with indirect methods, from which the presence of these germs may be inferred, rather than to expect the development of any method for their direct detection.

Something more must be said regarding the algæ. Investigators of low water life have been so attracted by the infinitesimal bacteria that these plants have been much neglected. Inasmuch as a once-polluted water cannot be said to be wholly purified until its nitrogen has gone through a complete cycle, until its nitrates have been used by the algæ and these have disappeared through starvation, it seems probable that a knowledge of their habits would enable us to use some of them in correcting bad conditions produced by other forms of life, and, on the other hand, to prevent the appearance of evils that sometimes arise in connection with an excessive growth of some species of these plants themselves.

Mrs. Richards, in her recent book, "Air, Water, and Food," has this to say concerning these plants:

"It is organisms of this class which give tastes and odors to water, and which, if enough were known concerning them, would probably give perfectly trustworthy information as to the past history or source of contamination. The two classes of organisms work in opposite directions, and, so long as food is present for either, life will increase with proportional rapidity. When a ground-water, free from all organic matter, but rich in nitrates, is exposed in an open basin, the rich growth of chlorophyll-bearing algæ follows as a matter of course; later, decay sets in and products of decomposition abound, the air above being the source of a constant supply of spores of all kinds.

"When a house or barn drain empties into a small, sluggish stream, it soon becomes filled with green plants thriving on the ammonia, and it is often possible to trace the source of pollution of a large lake by the line of green amœbina leading to the insignificant ditch.

"The effect of storage of water containing high nitrates in open tanks or reservoirs exposed to the collection of dust will be that spores of chlorophyll-bearing algæ, diatoms, desmids, etc., will soon develop, and will increase as long as the mineral food lasts. Only by protection from dust and light can such water be kept free from unpleasant accumulations of suspended organisms or from disagreeable tastes. Unpolluted surface-waters, on the other hand, improve on storage, as a general rule, if the basin is a clean one. The storage of polluted or clarified water is thus forbidden, since not infrequently the first indication of the pollution of a surface supply is given by the appearance of some member of that richly nitrogenous group of algæ called Cyanophyceæ, or 'blue greens,' from the presence of blue or purple coloring matter along with the yellow-green chlorophyll. Since this group of plants contains from seven to eleven per cent. of nitrogen, while other groups contain only one or two, it is evident that, if it is to flourish, more nitrogenous food must be supplied. This may be derived from fertilized fields, from decay of other vegetable life, as well as from the richer source of direct sewage; but, in any case, the growth of these plants is a sign of abundant food supply, which must be cut off if they are to be starved out, as they must be, unless they are removed while fresh by straining or skimming, for the odor of their decay is so intolerable as to preclude the use of the water. In

some cases the odor accompanying their growth renders the water quite objectionable, and neither natural nor artificial filtration is able to remove it.

"Either natural or artificial basins may have a collection of vegetable matter on the bottom, which slowly decomposes in summer, and, since the bottom water is colder, the resulting ammonia remains till the late fall overturn, when it is brought to the surface, where it favors the growth of diatoms and other cold-water plants. Certain diatoms, as *asterionella*, cause disagreeable odors. Such basins show the least ammonia in early October and the most in late November.

"In order to make any predictions as to the probable development of this flora and fauna of water, experience and at least a year's watching of any given supply are required, until more is known of the life-history of these forms of life. Nothing is more needed to-day than work along these lines. When may disagreeable tastes and odors be expected? What precaution or measures may be taken in each case to prevent them? These are the questions the water-works superintendent, equally with the consumer, is asking, for the most part vainly, as yet."

In some of the Eastern states these algæ have caused much trouble, especially where water is stored in ponds and small lakes. In our own state there has been some little trouble with tastes and odors, probably due to this cause, where a supply is obtained from a small stream, and, as the state becomes more densely populated and more water plants are built, many of which will be forced to collect and store the water, this is quite likely to increase.

At the present time in Kansas most of our water-works plants secure their supply from ground-water. This comes from that part of the rainfall, some twenty-five to forty per cent., that soaks into the soil and becomes partially or nearly purified by its action. This percolates more or less slowly downward, accordingly as the soil is close or open in texture, until it is stopped by some impervious stratum; then it flows in a sheet in the strata immediately above, which are completely saturated. This motion is a slow one, varying from only a few inches a day in close, clayey soils, to several feet in the open, sandy or gravelly layers, and is one of continuous progression. This sheet-water does not generally lie very deep and is constantly seeking an outlet, where it appears in the shape of springs, or breaks out beneath the beds of rivers or smaller streams. This movement of the underground water is too little realized by the average man who digs a well, and thinks, because the water derived is clear and cool, that it is a safe one for his use. The fact is, that even the isolated well of a farmer's home may harbor much of evil, while town wells as a whole are often much more dangerous than the public supply which may be furnishing a water less palatable or pleasing in appearance. The reasons therefor are not far to seek.

In the soil, which is acting as a filter for the purification of the water that passes through it, much the same agencies are at work in performing the task as were found accompanying the changes in surface-waters. In its top layers, chiefly within the upper twelve inches and rarely extending any deeper than three or four feet, are found the nitrifying bacteria, different in species perhaps from those at work in the adjacent streams, but yet with similar life-histories and producing similar results. In the shape of nitrates they return the nitrogen to the soil, where it can be taken up again by the tiny rootlets of growing plants. If these organisms have time to do their work, if the conditions of temperature, supply of oxygen, etc., are adapted to their need, then the water of the lower layers is freed from its organic nitrogen. An analysis of well-water then shows very little albuminoid or free ammonia and probably no nitrites, while all of the suspended matters that give cloudiness or turbidity to the water have been strained out and left behind in the interstices of the soil. On the other hand, if

the conditions are not right, or the passage through the soil is too rapid, the process of change may be interrupted, and the analyst will find the well-water containing evidence of the fact in the amounts of ammonia present. Cracks and seams in the soil, such as are liable to occur in clayey matter in dry times, afford quick passage; and in the case that the surface soil has been polluted in any way, as, for instance, by the throwing out of the discharges from a typhoid patient, such matter may suddenly make its presence in the water known by causing disease in those who use it. Again, at times of heavy and long-continued rains, by the saturation of the upper layers of the soil, the requisite amount of oxygen for the maintenance of the nitrifying bacteria may be much lessened, thus destroying the proper balance between these forms and the putrefactive bacteria which accompany the first stages of organic change. Here, again, the water would show an absence of nitrates and an excess of ammonia.

Generally speaking, the water derived from this underground flow, when filtered through an unpolluted soil, is a safe one; as safe, perhaps, as any that can be gathered. But there are troubles that are peculiar to this method of obtaining a supply, some of which have illustrations in our own state. The water is sometimes impregnated with iron in solution, which, on exposure to the air, becomes precipitated and forms a very light, finely divided mass of floating particles that are very hard to remove by any other means than filtration. The time required for ordinary subsidence is considerable and demands larger reservoir capacity than would otherwise be needed. If this iron-bearing water holds also imperfectly broken-down organic matter in solution, even if it be small in amount, under conditions when the average temperature of the water is somewhat above the normal, and in the presence of sufficient oxygen and the absence of light, there is very likely to develop, with great rapidity, an enormous growth of a species of bacteria called *crenothrix*. This microscopic plant is a simple cell enclosed in a gelatinous sheath, in which it secretes iron from the water. Though minute, it grows in large tufts and masses that are easily seen by the eye, fastened to the sides of a well or floating free in the water. It seems especially to attach itself to any woodwork, and also grows on the sides of the pipes of the distributing system to such extent as to reduce their effective size and increase the friction. Detached parts of these masses are carried far into the pipe lines and, not finding sufficient food or oxygen, die and decompose, giving a fishy taste and odor to the water and making it unfit for laundry use, because of the staining effect of the iron that was secreted. Where water is obtained through driven wells these organisms cause a deposit of iron, which closes up the fine holes or slits of the points, making frequent renewal necessary. These little plants are not at all uncommon, being found in some degree continuously in waters of this character. In some locations they seem to come and go, making only occasional trouble, while at some points it has been found necessary to abandon a source of supply because of them. The underflow of the Kansas river valley seems to be liable to trouble of this cause.

The storing of this water in tanks and reservoirs open to the light would prevent the development of this organism, but such method would probably lead to a development of the algae, which find an abundant food supply in the mineralized nitrogen.

The pipe-line system is not free from a large range of both plants and animals, which sometimes develop in such numbers as to cause a good deal of trouble. There is a small animal, barely visible to the eye, that grows in colonies or masses to such an extent as to coat the interior of pipes to the depth of half or three-quarters of an inch. This reduces the sectional area of a six-inch pipe by

fifteen per cent. or more, at the same time presenting a very rough surface to the flow of water. This animal, belonging to the family of the Polyzoa, forms for itself a tough, gelatinous sheath or case, containing its vital parts and having its mouth at the free end, surrounded by a fringe of tentacles, by means of which it draws in its food from the water. The other end of this case is fastened to that of some other individual from which the first had been born through a process of budding; so that a mass of these taken together much resemble moss, so much so that water-works men have given the name of "pipe moss" to these growths. The distribution system may be thus affected throughout its entire length; the smaller mains and the service pipes may be almost clogged; when deprived of sufficient food, the animals will die, their bodies will decompose, and the water drawn from the taps may be discolored and offensive. The pipe system at Lawrence gives some trouble in this way, and the evil is only kept in check by vigorous flushing of the mains during the summer season, causing a waste of water that is a serious tax upon the pumps.

So far as is known, neither of these organisms spoken of above is detrimental to health, though they cause annoyance to both the water-works men and the consumers. It is probably true that a reasonable amount of them, together with other similar organisms, is a benefit to the water of the mains, through maintaining a balance of life. Troubles seem to arise only when the conditions are such that some one form develops to an excessive degree. There are no known remedies which act as a specifics, and much more detailed knowledge of the life habits of the entire class of micro-organisms must be obtained before we can know how to deal with these problems in a satisfactory manner.

Of the last class of waters, those derived from deep wells, there is little to be said in this connection. Generally they are quite free from organic matter, which has all been changed and filtered out by the slow passage through the soil. Because of the solvent action of the water and the gases and acids which it carries, this class is more or less impregnated with mineral salts, sometimes to such an extent as to prohibit use in public supplies. In any case, it is the province of the physician to say whether the waters are fit for use. When designed for use in the arts or in manufacturing, these mineral constituents become of great importance, and the judgment of the chemist will alone control. The chief ingredient present in Kansas waters of this class seems to be salt, and this is encountered over a large part of the state at comparatively small depths below the sheet-water. In the southeast, on the flanks of the Ozark uplift, is found a very good water that serves as a source of public supply. But, as one goes westward from this range of mountains, the artesian water seems to have increasing amounts of mineral matter, though it is probably ample in quantity.

In all that has been said above, it has been assumed that the nitrogen, representing the organic matter, is the polluting material. But, in reality, this is not so. The true cause of most of the trouble to the human system that arises from a water-supply, lies in the admixture with it of something from the waste of human life itself. In all life it seems to be a general principle that each individual cannot exist in surroundings which are filled with the cast-off products of its own life activities. So the germs of water-borne diseases find their way into the water from some individual that is sick with one of them. The dejecta of a typhoid patient, thrown out without proper disinfection, may be washed into a clear, sparkling brook and carried by it to an impounding reservoir, and thence into a town supply, with the result that there is an outbreak of the disease. It does not follow that every one who drinks of the water must become sick, for this depends to some extent on the resistant power of the individual. But it is

true that every case of typhoid comes from a germ that is the seed of the disease, as surely as the acorn must precede an oak, and that the seeds of most cases are carried by drinking water. Marvelously evil results from apparently insignificant causes are not at all uncommon.

Sewage, then, must be considered as the worst element in producing pollution; matter that should by no means be discharged into any stream used for a water-supply, or cast onto any watershed from which such a supply is gathered. Right here comes a serious problem for the sanitarian, the engineer, and the citizen. Water is not only necessary to us in our life processes, but is also one of our chief burden bearers; principally the carrier of our wastes, which it is essential to remove from our environment. There is no more economical and sanitary way of transporting sewage than by means of water flowing in tight sewers. How can we continue this method and still preserve our sources of supply from sewage contamination? Or, if a supply is being polluted by sewage or other cause, how can we remove the polluting matter so as to furnish a safe supply?

The evils to be remedied are by no means new, and efforts have been made for fifty years or more to find a solution of the difficult problems. The density of the population of the older countries of Europe has forced these matters to the front, and more less successful attempts have been made to purify both sewage and water for public supplies, while stringent laws for the protection of streams and the collecting watersheds of reservoirs have been passed and enforced. For many years the chief incentive of those who advanced any new method of sewage treatment seemed to be the desire for a financial gain through the recovery from the sewage of its valuable constituents. Chemists can analyze sewage and figure the value of its nitrogen, phosphorus, etc., at current market prices, thereby estimating the total worth of yearly flow from any town. English estimates were placed at various figures, and the matter was gravely discussed by many of the leading scientists of the day. The value of London sewage was placed at from five million to twenty million dollars per year. A parliamentary commission argued the matter in minute detail, and arrived at a value of four cents a ton as a safe and conservative estimate. These discussions stimulated the inventive mind, with the result that the English government has granted 500 or more patents for the treatment of sewage. In many cases these proprietary methods were actually tried by companies formed to manufacture fertilizers for the open market, and so well were some of these enterprises exploited that they for a time paid the promoters, notwithstanding the fact that the product manufactured had little real value—by no means commensurate with the price asked therefor. These patents involved mainly the method of chemical precipitation, and called often for the use of precipitating agencies that would render the effluent more foul than the sewage itself.

Nor is it strange that the estimates of the fertilizing value of sewage should have turned attention to its utilization on land and the growing of crops through irrigation. Sewage farms sprung up all over England, and their financial success was much talked about, at first. But it was learned gradually that sewage farming with raw sewage and sewage purification were two very different things, that ran opposite rather than parallel; that when worked for the crops the effluent was poor; and when managed to produce a good effluent, the crops would not balance the outlay.

But the idea of financial gain has passed, and the underlying principle now is, as it should be, how to secure a good effluent, and so purify the sewage that it can be turned with safety into a running stream or on to a water-supply's drainage area. If, as a result of the method used, there is any return by way of a

crop or a remarkable product, this is now rightly considered as a happy result, but an entirely secondary one.

Chemical precipitation has been tried with all sorts of substances as precipitants, but securing only a partial purification, which amounts to saying that the effluent is still impure, and, therefore, unsafe. Where such a degree of treatment is wanted as will insure a stream from becoming offensive, and where this is not used for a source of supply, the method may find an application. An electrical treatment results chiefly in the formation of an antiseptic, which is supposed to act directly on germ life, and also of a precipitant set free by the current. It fails of complete action.

Broad irrigation results in a water-logged soil that neither benefits the crop or creates a good effluent.

Intermittent irrigation, rightly managed, and where a sufficient area of suitable open, sandy soil can be obtained, solves the problem quite well. It is, however, of limited application, because of inability to find the right kind of land in necessary quantity within easy reach of many towns. The method has been in use for some years, but the soil's action was not understood, or very imperfectly so, until the state board of health of Massachusetts, through its experiment station, at Lawrence, and the high skill and great ability of its experts there at work, discovered the matter and gave their results to the world. They first brought the slow sand-filtration process into line with exact science, whether applied to sewage treatment or the purification of water.

In this process the water or sewage is slowly filtered through a bed of sand about four feet thick. The filtering material may be of almost any average size of grain, from fine sand to coarse gravel, the rate of filtration and the size of the applied dose being regulated and properly adapted to each grade. In the upper few inches of this bed all of the chemical changes take place by means of the bacteria that there become established. These are very largely of the aerobic type, so that the filter has to be worked intermittently; that is, allowed to drain itself for a time between applications of doses, so as to draw into the sand the air that is needed by the bacteria for their life work. After these bacteria have become well established, which takes some time, the results are excellent. The experimental filters gave effluents in which nearly all of the nitrogen was changed to nitrates, and from which practically all of the organisms that were in the applied water or sewage were excluded; even such bacteria as did appear probably coming from the colonies that had established themselves in the underdrains, and not directly derived from the filter.

It is to be observed that these filters call into action only the aerobic organisms, and that, therefore, in order to attain a maximum efficiency, the first stage of the nitrogen change, due to the action of anaerobic forms, must be brought about before the application of the liquid to the filter; that is, the solids must have been broken up and the organic matters rendered soluble. As a matter of fact, both forms exist in these filters, or, rather, there are forms present that can act in both ways, as anaerobic when the filter is saturated, and as aerobic when working in the presence of oxygen. In case the filters are treating a sewage that comes from a long line of sewers, the first stage has been passed to a large degree by the time the filters are reached, the anaerobics doing their work in the sewers, leaving only a small part of the organic nitrogen to the action of the forms that can adapt themselves. Also in the case of the filtration of river-water, much of the work of this first stage has been already accomplished. Hence, good results can be expected. But if a fresh, raw sewage is to be treated, these filters will give trouble, through the deposit of unbroken-down solids that quickly

clog the interstices of the sand and prevent the passage of water and the introduction of the needed air. But the method has found successful application on a practical scale for both sewage and water treatment.

Stimulated by the necessities of their environment, the English people have been developing a line of treatment that perhaps more closely follows nature. In 1896 the town of Sutton abandoned chemical precipitation, and installed Mr. Dibdin's scheme of "contact beds." In this the sewage, after a mechanical straining to take out the coarser solids, is run onto a bed of coarse burnt ballast, where it is held for a time, that it may deposit the suspended matter and be worked upon by the anaerobics, thus forming what is called the "contact." The effluent from this "bacteria tank" is then run onto a bed of fine coke-breeze which is operated intermittently, with the intention of getting the action of the aerobics.

The two tanks form a "double-contact" system. They are arranged in duplicate, so that each pair has a period of rest and aeration. From this it seems that reliance is placed on aerobic filters and organisms for combined liquefaction and nitrification in the same bed. While the results are generally good, they are somewhat variable, the reason for which appears to be as follows: The two classes of organisms are mutually antagonistic; an excessive development of one excludes the other, so the true anaerobics do not have opportunity to become well established in the first tank because of its "resting empty" period, while those forms that can adapt themselves are under the necessity of changing their habits every few hours. A further result is that some organic matter is carried over to the second bed without undergoing the stage of change, thus forcing upon that bed some of the work that should have been done in the first. The whole bacterial process is thus frequently disturbed. There is also the screened sludge first taken out to be separately dealt with.

In 1895 Mr. Cameron introduced at Exeter the "septic tank." In this system the raw sewage as it comes from the mains is passed into an underground air- and light-tight tank of such capacity as to hold the flow of twenty-four hours. Both inlet and outlet are below the surface of the water, so that the gases formed do not escape and floating solids are retained. During the twenty-four hours that the sewage has to pass through it is attacked by the anaerobics, which find the conditions very favorable, with the result that all solids of whatever organic nature are broken up and largely dissolved. The heavier mineral matter is intercepted in a grit chamber adjacent to the tank before the admission of sewage. The surface of the tank is covered by a thick, tough scum, which catches and holds the lighter floating solids until they are broken up. On the bottom, there very slowly accumulates a deposit of mineral nature and organic matter that decomposes but slowly. After four years of use this deposit was only four feet thick, representing the total residue of the sewage of a population of 1500 people. The gases formed are inflammable and may be utilized, the pressure being obtained by raising the surface of the contents of the tank by changing the elevation of its outlet, and confining the gas between this and the arched roof.

The effluent from this "septic tank" is run over a weir in a thin sheet to aerate it and then discharged onto filter-beds of coke-breeze, where the nitrifying organisms do their work. Here, then, is a true separation of the two classes of bacteria, and the requirement of regular and continuous action is at least met in the first part of the process.

You will remember, however, that there are three stages of action and three classes of bacteria at work before nitrates are reached. Triple-contact beds, or the addition of a third filter to the septic system, have been suggested as adapted

to these stages, but Mr. Scott-Moncrieff has devised a system that more nearly causes a separation of the different bacteria than could be hoped for from these suggested schemes.

In this the sewage is passed upward through a coarse filter from a shallow chamber underneath, thus forming right conditions for the anaerobics, which seem to be able to deal with all of the solid matter and prevent its accumulation. The overflow from this bed is discharged automatically and continuously onto a series of shallow trays, arranged each over the other, and each receiving its supply from the discharge from the one next above. The automatic device works periodically, so that the materials of the trays are aerated regularly, the sewage trickling down through them and carrying air along with it. There is a rapid formation of nitrites in the two upper trays, but this decreases rapidly in those lower down, and runs out entirely in the eighth and ninth, the last of the series. The lower a tray the more active are the bacteria that produce nitrates, and in the lowest they seem to be the only organisms at work. The entire passage through the nine trays takes only about eight or ten minutes, and the rate of filtration is about one million gallons per acre per twenty-four hours. Mr. Rideal, an English expert, claims that this process gives better nitrate results than any other with which he is acquainted.

In the accounts of this and other English work which I have seen the results are stated in percentages of nitrogen that have been removed, without any statements of the bacterial purity of the effluents secured. This can be inferred to some extent from the results of chemical analyses, and yet must be considered a serious lack to our full understanding of the matters presented.

In attempting to use the Massachusetts methods for the purification of the waters of the region west of the Alleghany mountains, it has been found that they are not applicable. The fine, clayey matters that are carried in suspension in all western rivers—matter that is absent from the New England streams which flow from granite and sandstone hills—clog the pores of sand filters and prevent their use as bacteria beds. Some waters lack organic matter in the form needed to coat sand grains with a gelatinous envelope. Resort must be had to other methods. So there is now going on an active study of what is called the American system, or rapid mechanical filtration. The typhoid death-rate of Louisville, Cincinnati, and Pittsburg, as well as other inland towns, has driven them to elaborate scientific investigations as to the best methods for treating their water-supplies in order to remove the fine silt and render them safe.

The process is not biological, but a combination of chemical and mechanical methods. As worked out at Cincinnati, the river-water was first allowed to settle for some hours in an open reservoir, then pumped into tanks, where it was mixed with a precipitating agent, sulphate of alumina or crude alum, and thence into tanks containing about four feet of sand, through which it passed into a clear well and into the city mains. The precipitate formed by the alum is flocculent, and entangles much of the organic matter from the very start. In the filter the alum is caught by the sand surface, where it forms a gelatinous coating that strains out both the fine silt and all suspended matter, including even such minute things as the bacteria. The bacterial efficiency rarely dropped below ninety-five per cent. and averaged about ninety-nine per cent.; and it was further found that when this was good the character of the effluent was also satisfactory as to clearness and the removal of organic matter.

When the alum layer becomes too thick and offers too much resistance to the flow, the filter is washed by its own filtered water until the collected matter is

driven out. This is done by forcing water from below upwards, at the same time that a mechanical stirring is given the sand.

The rate of filtration used was about 120 million gallons per acre per day, which is 100 times faster than is attained by the slow sand method. An average amount of 1.6 grains per gallon of the alum was used, an amount that is too small to affect the water in any injurious way for domestic use, though slightly increasing the hardness and the tendency to the formation of boiler scale, a point that is considered as being offset by the removal from the raw water of the suspended solids.

One thing that is learned from a study of the investigations made in many localities is that the methods used in one place may not be at all successful at another. Each water or each sewage has its own peculiarities; each location or climate may have its own characteristic fauna and flora among the lower organisms; and all these things must be studied carefully before right means can be used to secure the desired results. Some great general principles must underlie all efforts, so that results elsewhere can be taken as guides, but only as such.

Here in Kansas is a field about which we know very little along these lines. Some geological work has been done, and is now being carried on in a systematic way by the university survey. Some waters have been analyzed by the chemists of the various institutions or reported upon by some one connected with the state board of health when their purity has been questioned. Biologists have done something with the low fauna and flora. But all this has been with no systematic purpose in view, and the time is soon coming when the results of such investigations in our state will be of very great value. At no time in the world's history has there been so wide-spread and general an interest in matters pertaining to public health as the present, and it is hoped that Kansas may put herself in line with the general movement by furthering all investigations that may add to our knowledge, by wise health legislation, and by giving her board of health such authority as will render its efforts effective. This board should have the duty given it to supervise the installation of all public water-supply or sewerage plants, the right to demand that existing plants be conducted in a way not detrimental, and be further charged with the duty and given the money for the study of questions relating to these things that may arise.